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MECHANICS OF CONTACT INTERACTION OF ELASTIC HELICAL HONE AND MACHINING SURFACE

The principle of studying the deformation of the elastic deformable shell of the elastic helical hone is considered in the article. The obtained theoretical and experimental studies have been taken into consideration. As a result, we determined the non-uniformity of the elastic helical hone in the radial direction on each turn of the elastic deformable shell. The method of preparation of the elastic helical hone for the processing of precise holes with the possibility of correction in automatic mode in the machine was developed.

Key words: honing of holes, contact interaction, elastic deformable shell, elastic helical hone, adjustment of radial size.

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МЕХАНІКА КОНТАКТНОЇ ВЗАЄМОДІЇ ПРУЖНО-ГВИНТОВОГО ХОНА І ОБРОБЛЮВАНОЇ ПОВЕРХНІ

В статі розглядається принцип дослідження деформації пружно-деформуємої оболонки пружно-гвинтового хона з урахуванням отриманих теоретичних та експериментальних досліджень. В результаті чого було визначено нерівномірність пружно-гвинтового хона в радіальному напрямку на кожному витку пружно-деформуємої оболонки. Була розроблена методика підготовки пружного-гвинтового хона для обробки прецензійних отворів з можливістю правки в автоматичному режимі на верстаті.

Ключові слова: хонінгування отворів, контактна взаємодія, пружно-деформуєма оболонка, пружно-гвинтовий хон, регулювання радіального розміру.

Problem statement and analysis of research

The analysis of the mechanics of contact interaction of the diamond-abrasive tool with the machining surface allowed putting forward a number of requirements for the implementation of the stage of the prior passes and the stage of the final passes. These requirements are fundamentally different [1].

At the stage of prior passes, it is necessary to preserve the local guaranteed gap in the contact with the "hone-machined surface" for removing chips. The cutting process is significantly influenced by volume of the gap in the contact, that is the space between the reliefs of the hone and the machining surface at a certain length after converging them under the action of the applied loading.

Insufficient volume for chip removal leads to the tool greasing and the reduction of its performance.

At the stage of final pass, it is necessary to ensure the maximum approximation of the hone geometry to the geometry of the machining surface [2].

The main disadvantage of hone operation of traditional design is the presence of uneven wear, which can not be eliminated by the adjustment of radial size control systems.

The authors of the works [2, 3, 4, 5, 6] offer to reduce the unevenness of wear using combined kinematics of movements and variations in pressure during the honing process. But with such a change it is possible to achieve only the reduction of uneven wear by 50% [3]. In addition, for the implementation of combined kinematics of movements and variation of contact pressures, the machine tool becomes considerably complicated [3]. In connection with the above-mentioned facts it is expedient to change the geometrical shape of the cutting surface for prior and final passes of honing. At the same time, this change in geometry should be aimed at preserving the geometric part of the hone that will carry out the clean passes. Generally, it is necessary to meet some requirements for the implementation of prior and final honing, including:

1. Division of the cutting surface of the hone into the parts for prior passes and the parts for final passes [3].
2. The part of the cutting surface which treats the final pass must not interact with the machining surface by providing the gap necessary and sufficient to maintain the lead-in action in the process of prior honing.
3. Providing relatively high contact pressure and relatively increased space in the contact area for removing chips at the stage of prior passes of honing holes.
4. Ensuring a sufficient contact plane at the final pass of the honing holes.

Topicality of research

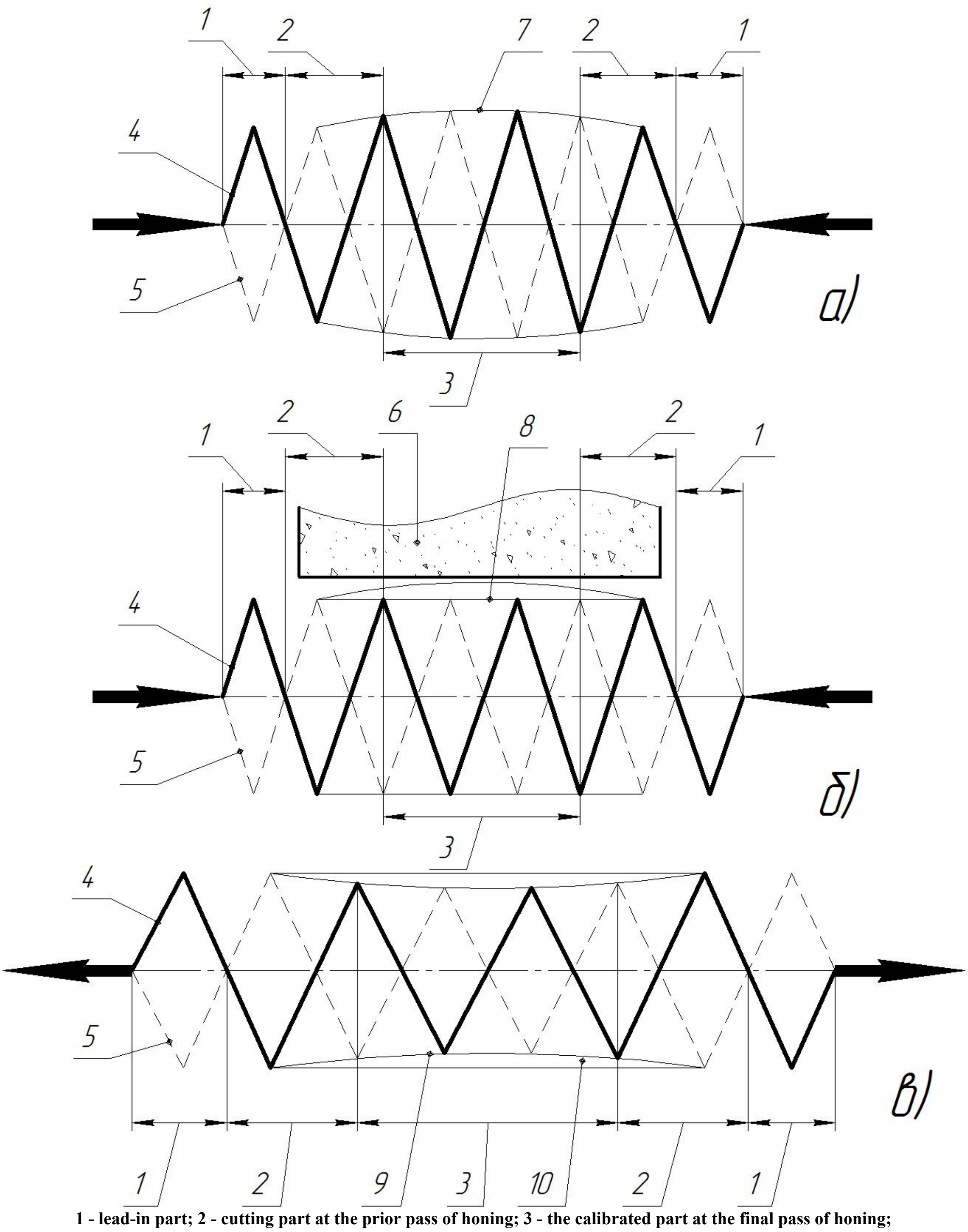
The requirements for the quality and accuracy of processed precise holing are constantly increasing. The quality directly affects the reliability of mechanisms. Therefore, the study of interaction between the elastic helical hone and the machining surface in the process of honing is a very important task.

Research of the mechanics of contact interaction of elastic helical hone in the process of honing

Taking into consideration the above-mentioned facts, the synthesized elastic helical hone must meet the requirements for the machining in the conditions of the stage of prior passes, as well as for the conditions of the stage of final pass.

Thus, the possibility to influence the mechanics of the contact interaction due to design development of the hone will ensure that the requirements are met.

Figure 1 shows the schematic diagram of the change in geometry of the elastic helical hone as a result of design development. Initially, the elastic helical hone is deformed to a nominal design value along its own geometric axis (Fig. 1, a).



1 - lead-in part; 2 - cutting part at the prior pass of honing; 3 - the calibrated part at the final pass of honing; 4 - the contour of elastic helical hone; 5 - projection of the contour when turning to angle 180; 6 - grinding wheel; 7 - barrel-shaped surface; 8 - cylindrical surface; 9 - saddle-shaped surface; 10 - space for moving out of the zone of interaction with the treated surface and the formation of the lead-in section;
a) the scheme of probable deformation of the outer contour of the elastic helical hone; b) the grinding scheme of the external contour of the elastic helical hone in nominal size under the conditions of compressed state; c) the scheme of reverse deformation of the outer contour of the elastic helical hone due to the unloading of the compression forces to obtain the radial size of the original value
Figure 1. The shape of the surface of the elastic helical hone in the longitudinal section

In this case, the outer surface is likely to get a barrel shape 7. The obtained specified changes in geometric shape and elastic deformation are described by the system of equations [1]:

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(1)

where φ_3 – twist angle or the lift angle of the helical line after loading;

P_z – axis force;

R – radius of the cylinder of the body of elastic deformable shell along axis line of the crossed cut;

i – number of spirals of elastic deformable shell;

σ_2 – springiness modulus of the second kind or slip modulus;

I – inertia moment, geometric characteristics of toughness while twisting;

α – lift angle of the helical line before loading;

λ – draft value of elastic deformable shell while loading;

φ_i – lift angle of the helical line after loading.

In this fixed position, the grinding of the surface is performed until the values of the nominal diametric size are reached. The cylindrical surface 8 should be treated on length 3, and partly on length 2.

In this case, the outer cylindrical surface of the elastic helical hone is conventionally divided into three parts, including:

1 - the lead-in part with the surface formed by the incomplete turn;

2 - cutting part with the surface formed by the complete turn. This surface is processed by cutting first and reproduces the sharp-top form on the surface;

3 - the calibration part which is adjacent to the cutting part and reproduces the flat-top form on the surface [1].

Thus, the elastic helical hone is fixed in accordance with Fig. 1b and is used for the final pass of honing. This is due to the fact that the hone has a sufficient supporting surface as a calibrating part of cylindrical shape which meets the requirements for the final pass.

Fig. 1 presents the scheme of the elastic helical hone adjusted for the prior pass by means of release and elastic deformation in the opposite direction and reduction of the diametric size.

In this case, the part of the outer surface gets a saddle-shape form 9, forming space 10 for removal of the chips. This form meets the requirements, which ensure its functioning as a lead-in section.

Fig. 2 shows the longitudinal sections of the elastic helical hone that correspond to the lead-in part (Fig. 2, a, c), the cutting and calibration part (Fig. 2 b, d). At the same time Fig. 2, d shows the interaction of the calibration part of the hone with the treated surface in the conditions of the prior pass with the presence of gap 6.

In fig. 2, b the calibration part interacts with the treated surface in the final pass.

Thus, the synthesized elastic helical hone belongs is the instrument with a developed micro-relief, with a relatively minimized bearing profile length and the ability to change the geometry of the contact during the honing process.

Fig. 3 shows the protocol of measuring the elastic helical hone, which was measured on the coordinate-measuring machine.

The protocol contains measurements on four points located at the angle of 90° to each other. The measurements were carried out in three states of the elastic helical hone.

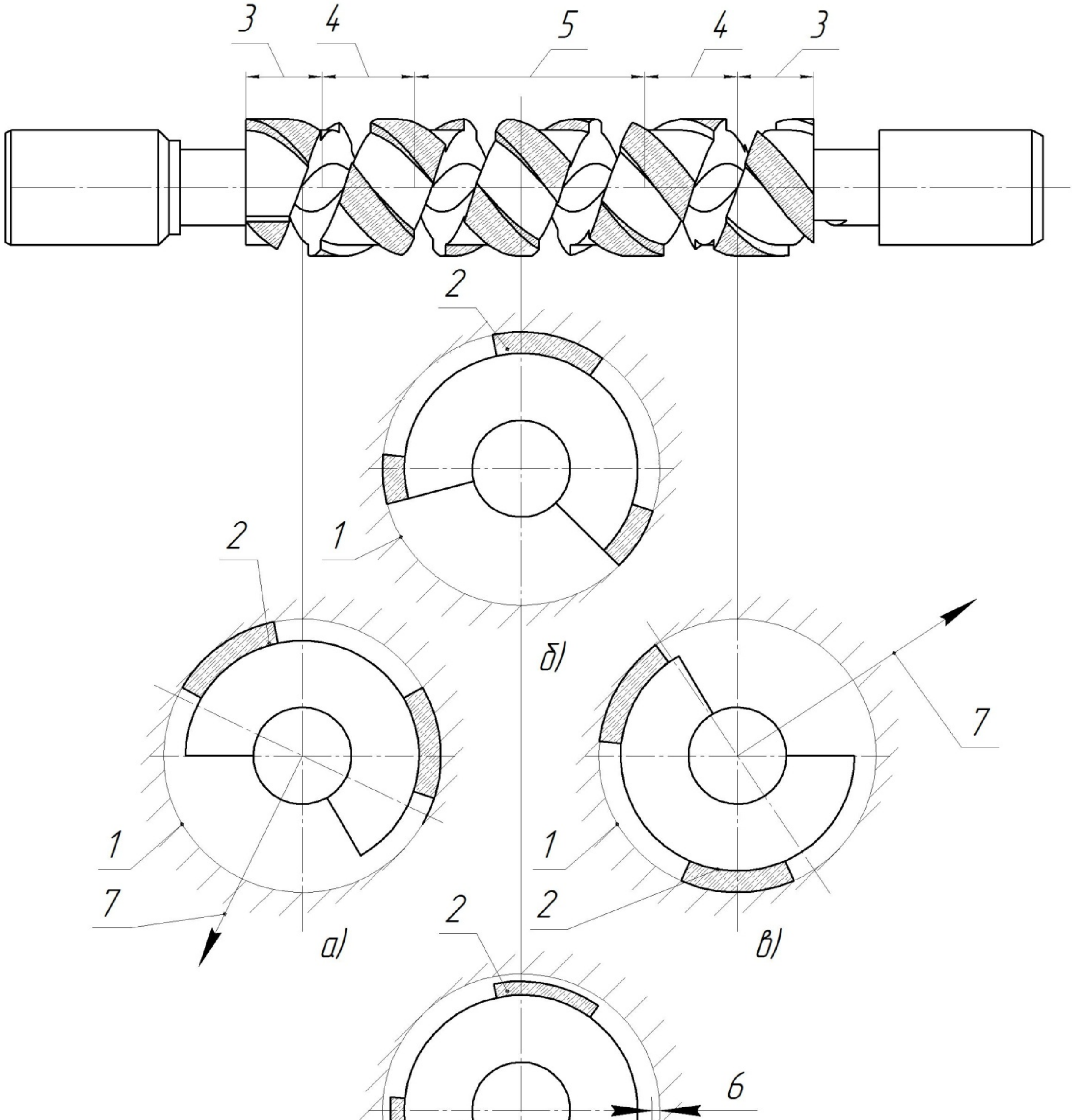
The first measurement was carried out in the conditions of maximum required compression of the elastic helical hone. In this case the outer contour has the barrel-shaped form with the extreme point of ~ 25 microns, which is located in the centre of the calibration part.

The second measurement was carried after the grinding of the working surface. In this case, the deviation from the cylindrical form fluctuates within 5 ... 6 microns.

The third measurement was carried out in the conditions of release of the elastic helical hole to make the prior pass. In this case, the part of the outer contour had the saddle-type shape with the extreme deviation of 10 ... 15 microns.

The change in the geometry of the hone can be carried out automatically on special machines equipped with automatic control systems.

When machining is carried out on universal machines, the hones are adjusted in advance, depending on the type of pass.



1 – contour the machined hole; 2 – diamond abrasive stones; 3 – lead-in part; 4 – cutting part at the stage of prior pass of honing; 5 – calibrated part after final pass of honing; 6 – gap in the area of calibration part to ensure functioning, as a lead-in section; 7 – vector of the direction of the degree of freedom for the orientation of elastic helical hone along the contour of the hole;
a) the diagram of contact of lead-in part; b) the diagram of the contact of the calibration part at the final pass; c) diagram of contact of the outlet part; d) diagram of contact of the calibration part at the prior pass
Figure 2. Interaction of elastic helical hole with machining surface

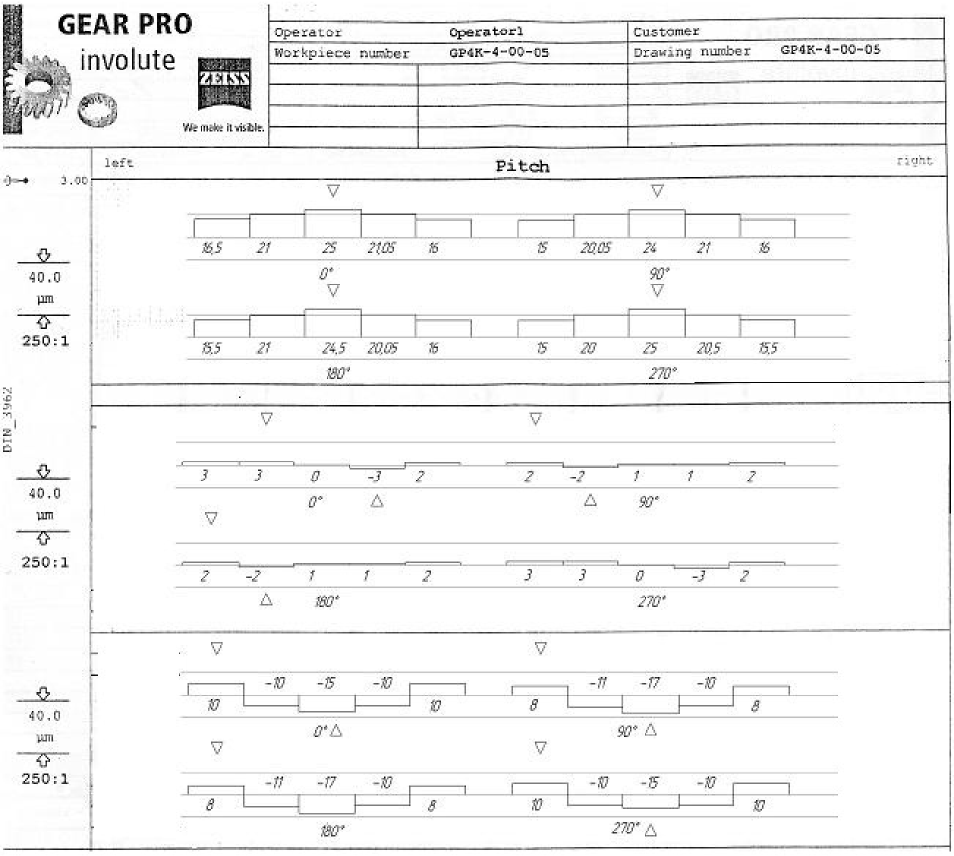


Figure 3. Protocol of measuring the outer cylindrical contour of the elastic helical hone on the coordinate measuring machine

a) b)

1 – Carl Zeiss CONTURA G2 coordinate measuring machine; 2 – measuring probe; 3 – elastic helical hone.
a) a general view of the area of measurement of the outer cylindrical contour of the elastic helical hone; b) the area of measurement of the outer cylindrical contour of the elastic helical hone
Figure 4. Carl Zeiss CONTURA Coordinate Measuring Machine

Conclusions

Consequently, as a result of the study, it was discovered that the actual growth of the diameter has maximum value inside the elastic helical hone with a moderate decrease to the ends, forming a barrel-shaped form, with the value of the difference being within 5 microns by the results of measurement and does not affect its performance, taking into account the proposed methodology preparation for the exploitation.

Development of the method of preparation for the exploitation became possible due to the study of the mechanics of contact interaction the elastic helical hone and the treated surface.

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